RECONSTRUCTION OF PAST CLIMATIC PROXY SERIES

John E. Kutzbach

Wisconsin University

Prepared for:

Air Force Office of Scientific Research
Advanced Research Projects Agency

30 January 1975

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

076035

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFOSR - TR - 75 - 0177	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): RECONSTRUCTION OF PAST CLIMATIC PROXY SERIES	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): John E. Kutzbach	8. CONTRACT OR GRANT NUMBER(s): AFOSR-72-2407
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Center for Climatic Research, Institute for Environmental Studies, Univ. of Wisconsin-Madison, WI 53706	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 64706E; ARPA Order 2221
11. CONTROLLING OFFICE NAME AND ADDRESS: Advanced Research Projects Agency/IPT, 1400 Wilson Boulevard, Arlington, Virginia 22209	12. REPORT DATE: 30 January 1975
	13. NUMBER OF PAGES: 23
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Air Force Office of Scientific Research/NP, 1400 Wilson Boulevard, Arlington, Virginia 22209	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

past climates; climate change; pollen; tree-rings; varves; calibration functions; Holocene.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Reconstruction of past climates from pollen data, tree-ring data and historical data is described. The pollen-climate relationships cover the past 10,000 years and deal with North America and portions of Eurasia. Detailed climatic information from 1000-year records of annually laminated lake sediments and tree-ring records in central North America (Great Lakes area) is also described.

DD FORM 1 JAN 73 1473 EDITION OF 1 I

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AFOSR - TR - 75 - 0177

[redacted] FINAL REPORT

"Reconstruction of Past Climatic Proxy Series"

Submitted to
DEPARTMENT OF THE AIR FORCE
Air Force Office of Scientific Research (AFSC)
1400 Wilson Boulevard
Arlington, Virginia 22209

30 January 1975

Principal Investigator: John E. Kutzbach
Phone: (608) 262-2839
Center for Climatic Research
Institute for Environmental Studies
University of Wisconsin, Madison, WI 53706

Program Manager: William J. Best
Phone: (202) 694-5454

Effective Date: 1 July 1972
Expiration Date: 30 June 1974
Amount of Grant: $101,158
Grant No: AFOSR 72-2407
ARPA Order: 2221-3
Program Code: P10

Sponsored by
ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 2221-3

ia

1. Introduction

Our research effort in reconstructing past climates can be divided into four categories:

1) Development of data banks on past environments.
2) Development of calibration functions to make possible the interpretation of environmental change in terms of changes of climatic variables.
3) Reconstruction of spatial patterns and time series of past climates.
4) Interpretation of past climates.

The focus of our current efforts is the Holocene, approximately the past 10,000 years.

Four specific projects are reported here:

1) Pollen records of the last 11,000 years - obtained from lake sediments - dated with radiocarbon.
2) Pollen records of the last 2000 years - obtained from annually laminated lake sediments - dated by counting.
3) Tree core records of the last 200-300 years.
4) Historical (non-instrumental) records.

These four projects are described in detail in our research proposal (30 June 1974-29 June 1975) and their current status is summarized below.

2. Current Status

2.1 Pollen Records (the last 10,000 years)

a) Eastern North America (T. Webb III)

Using all available radiocarbon-dated fossil pollen cores from eastern North America, maps have been prepared showing the changing patterns of the

various pollen types at 1000 year intervals over the past 11,000 years. Maps for spruce, pine, oak and total herb pollen have been drafted for 11,000; 10,000; 9,000; 8,000; 7,000; 4,000; and 2,000 years ago. Difference maps have also been prepared showing the changes in pollen-type distribution from one interval to the next. Finally, these maps are being used to trace the migration of ecotones during the Holocene (see Fig. 1).

A manuscript describing these maps is now near completion.

Figure 1 shows the movement of conifer forest - tundra (A), deciduous forest - conifer-hardwood forest (B), and prairie border (C) ecotones, based upon analysis of C-14 dated pollen cores in eastern North America. Isolines are labelled in thousands of years before present. Thus, figure 1A illustrates the northward retreat of spruce forests between 11,500 and 8,000 years ago; figure 1B illustrates the northward movement of deciduous forests between 10,000 and 7,000 years ago; figure 1C illustrates an eastward movement of the prairie border between 11,000 and 7,000 years ago, followed by a westward movement between 7,000 and 2,000 years ago.

b) Soviet Union (G.M. Peterson)

The past year was spent largely in library research, reviewing Soviet and American bibliographies to determine the amount of information available on Holocene palynology in the Soviet Union. The preliminary results indicate an abundance of pollen data for the Holocene, particularly for the European USSR, including surface samples, pollen diagrams, and radiocarbon dates.

Approximately 100 published references were obtained with surface pollen data for over 700 locations in the USSR (see Figure 2). We are presently verifying sample locations and standardizing the pollen data for computer mapping with the SYMAP

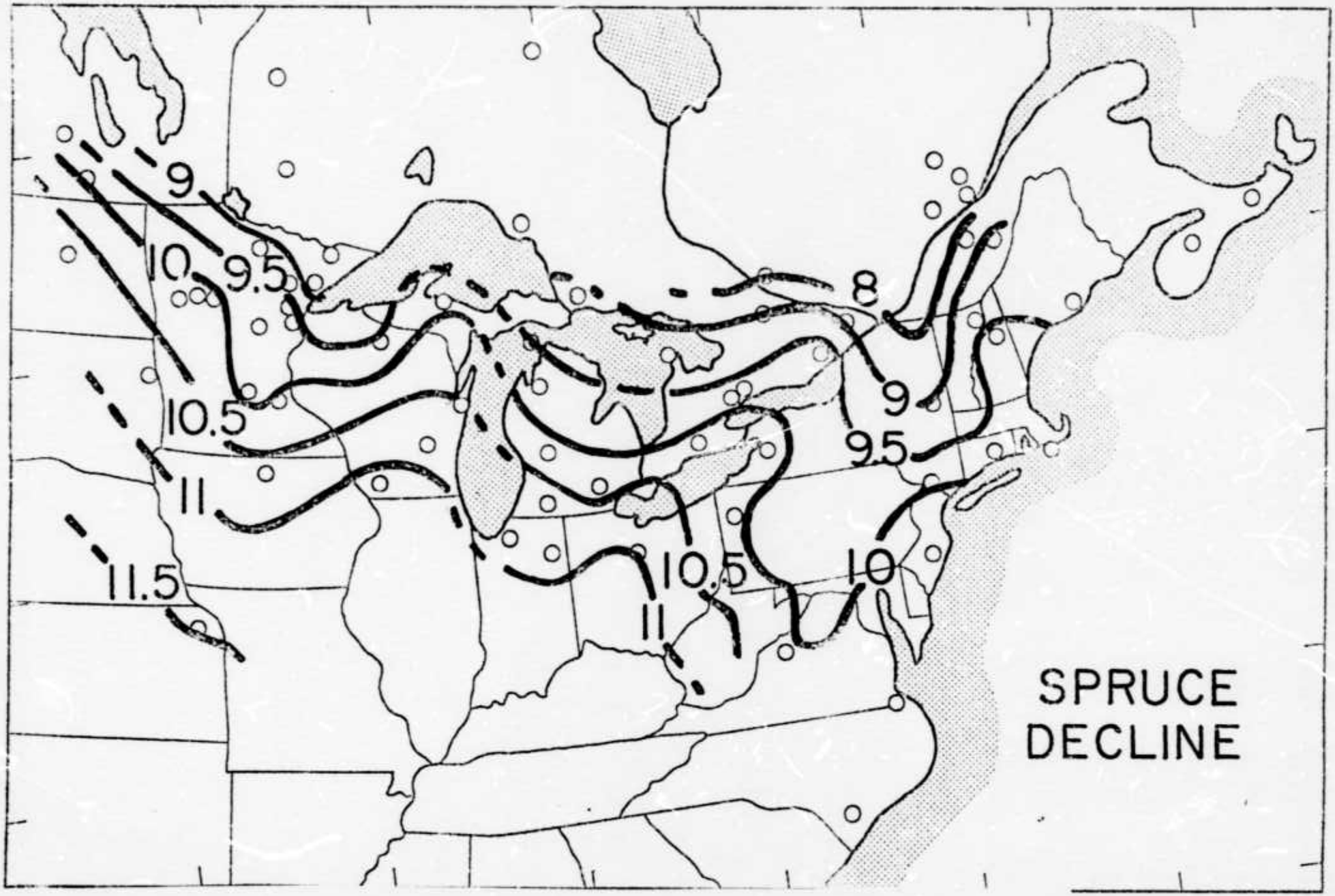


Figure 1A - Movement of conifer forest-tundra ecotone.

2.A

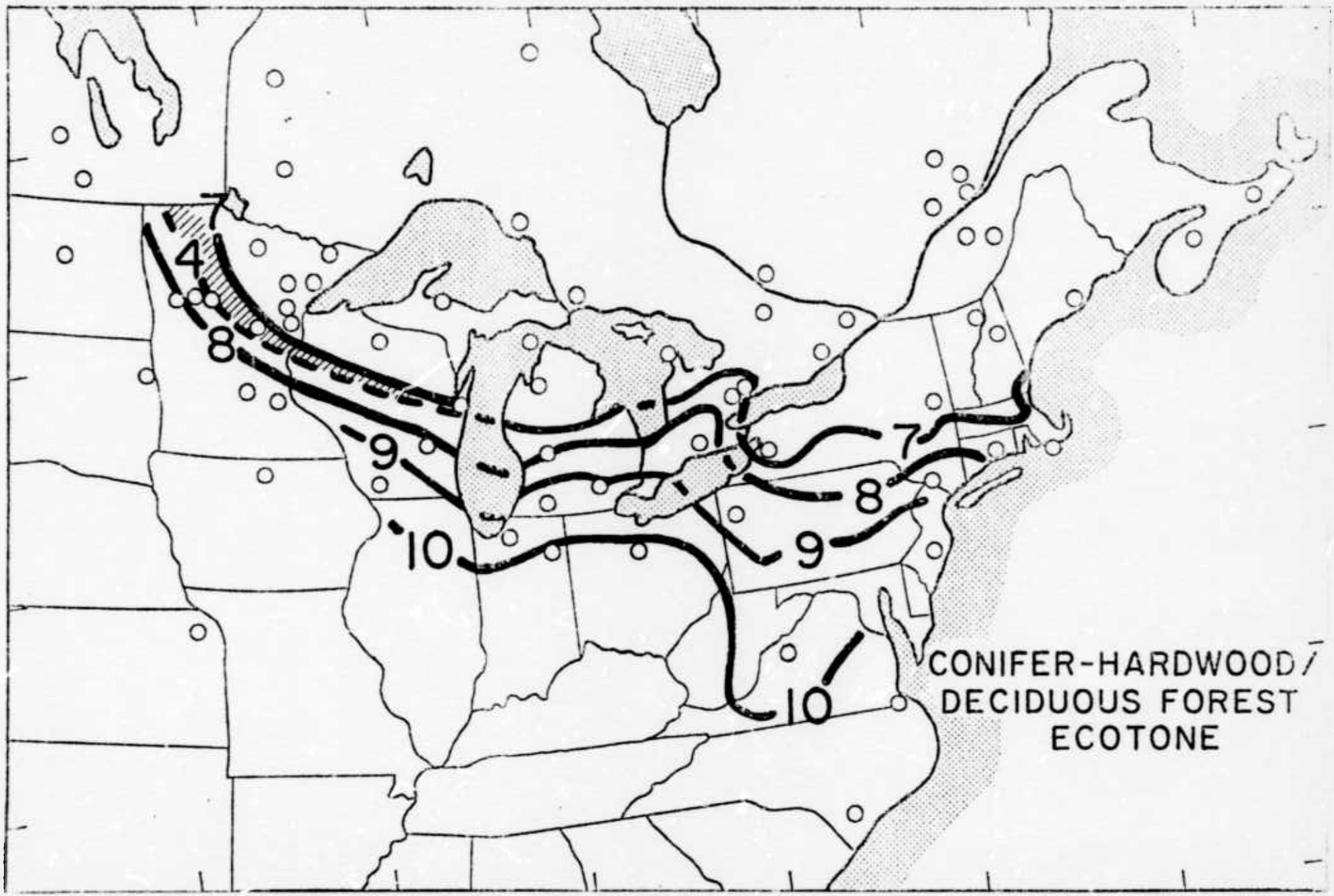


Figure 1B - Movement of deciduous forest - conifer-hardwood forest ecotone.

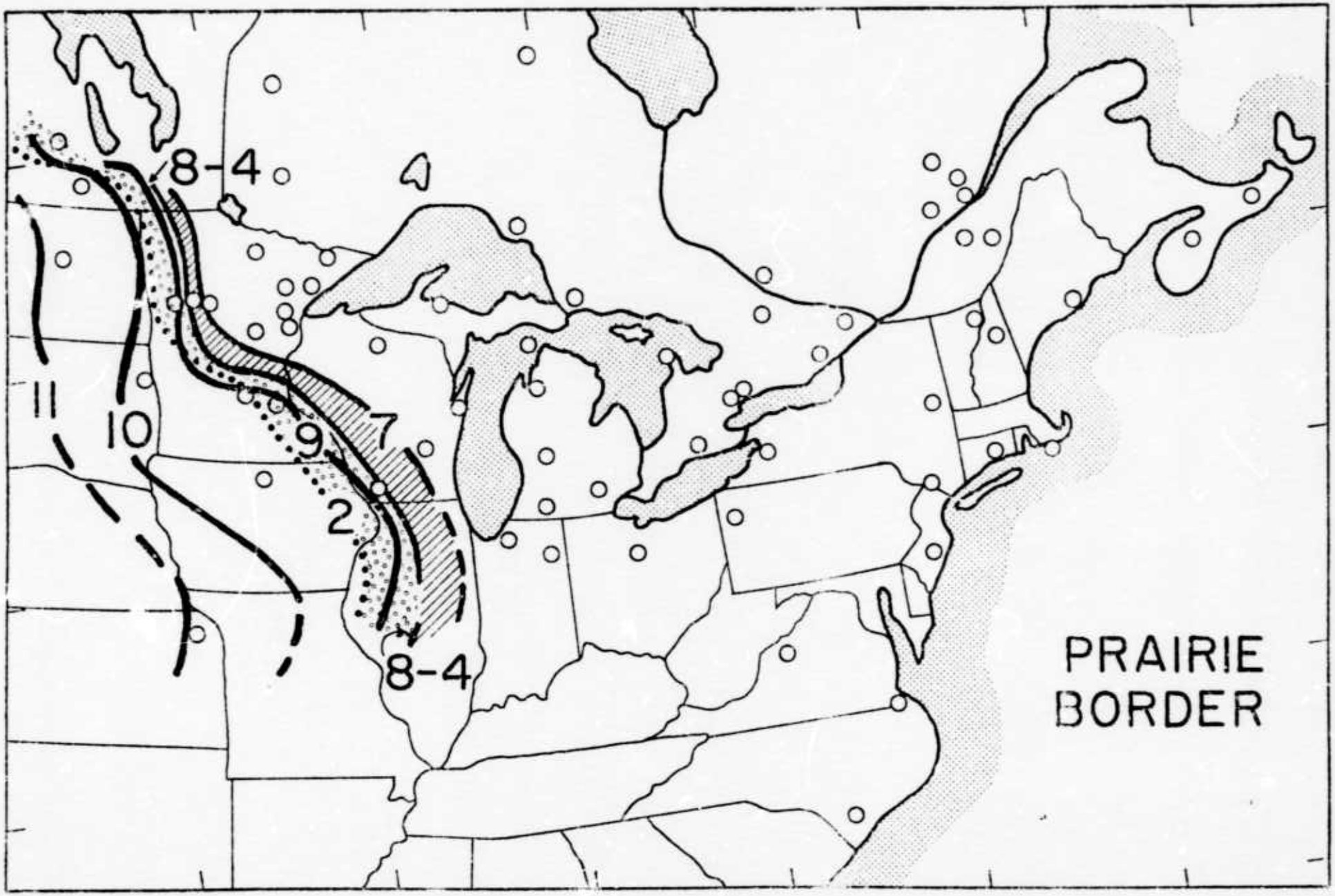


Figure 1C - Movement of prairie border ecotone.

program. The immediate goal is to produce a set of isopoll maps for the USSR similar to those for eastern North America (Webb and McAndrews, in preparation).

Holocene pollen diagrams are also abundant. Neishtadt (1957) used 155 pollen diagrams to reconstruct vegetation history for the USSR in the last 12,000 years (see Figure 3). Many more pollen diagrams have subsequently appeared, and radiocarbon chronologies are fairly well established for the European USSR. Figure 4 shows the locations of 23 dated pollen diagrams in the Soviet Union.

The majority of surface samples and pollen diagrams are from the region west of 90° E, and the majority of C-14 dated diagrams are from the area west of 45° E. The area from European USSR to the Western Siberian Lowland will thus be most fruitful for climatic reconstructions, although dated pollen diagrams and surface sample data are also available from northeastern Siberia, Sakhalin, and the Kamchatka Peninsula.

A recent reference by Grichuk (1973) indicates that very little has been done in the USSR to quantitatively reconstruct past climates from pollen data. We have found only one such reference for the Holocene (Grichuk, 1969). The attempt by Grichuk was based on the geographical extent of certain species, and is less sensitive than the multivariate statistical techniques which will be used in the present study.

The present study, in conjunction with those currently in progress for eastern North America (Webb, et al.; Swain in prep.) will provide reconstructions of synoptic paleoclimatic patterns over a large segment of the northern hemisphere.

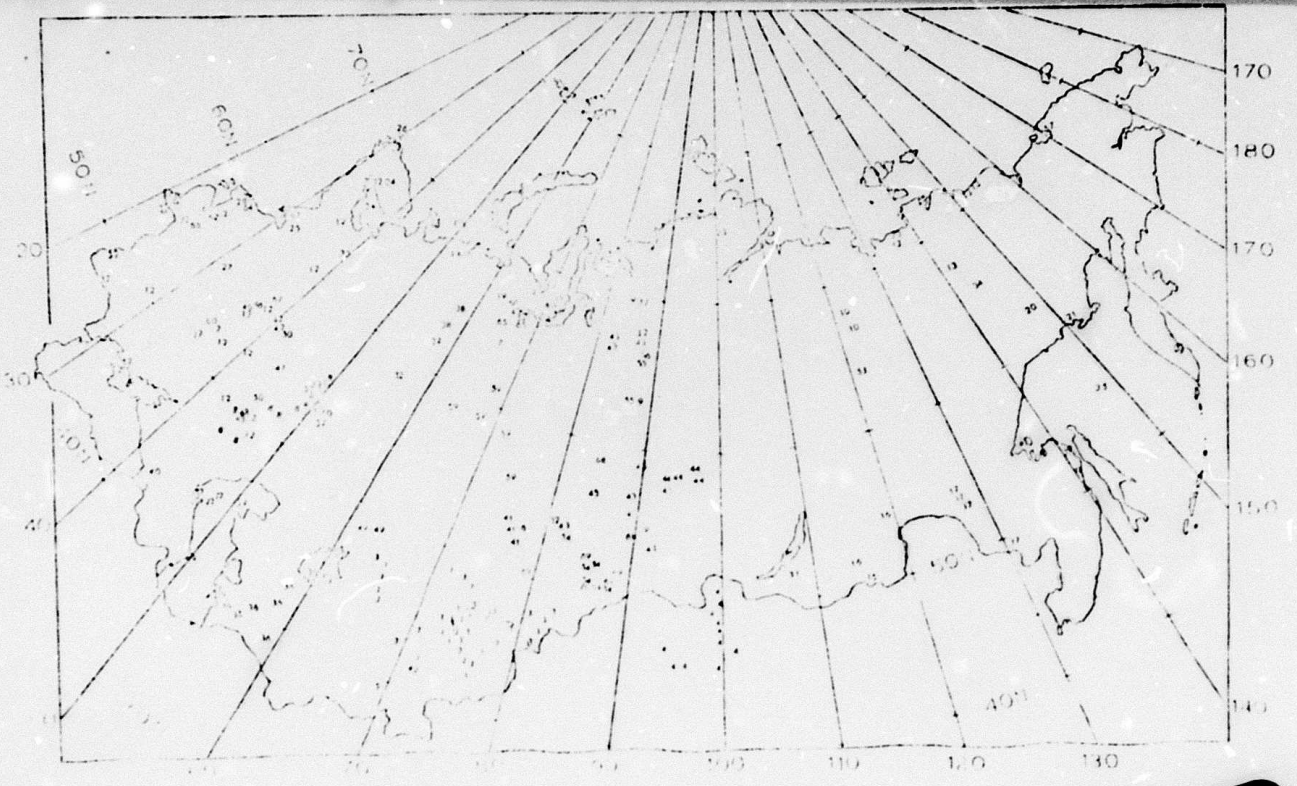


Figure 2. Surface Pollen Sites - USSR (Generalized), G.M. Peterson (1974).

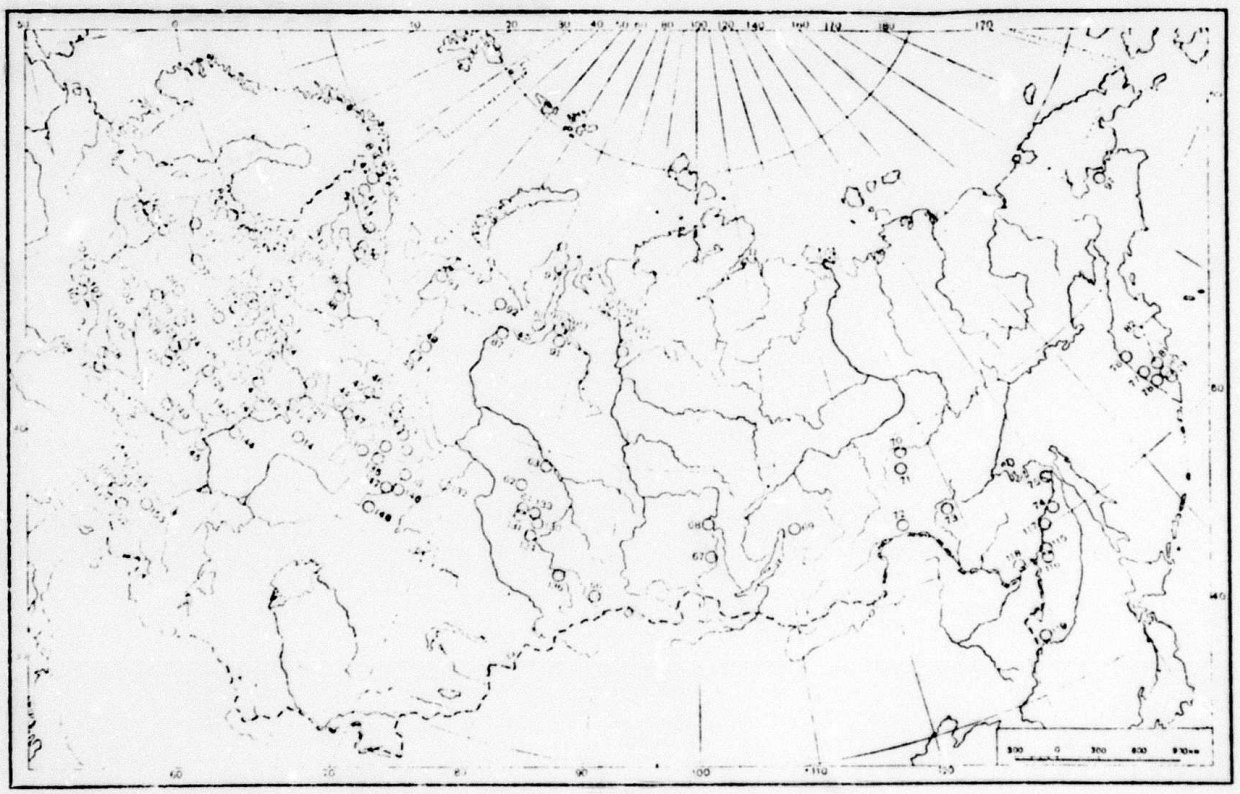


Figure 3. Location of 155 Holocene pollen profiles used by Neishtadt (After Neishtadt, 1957, Fig. 2).

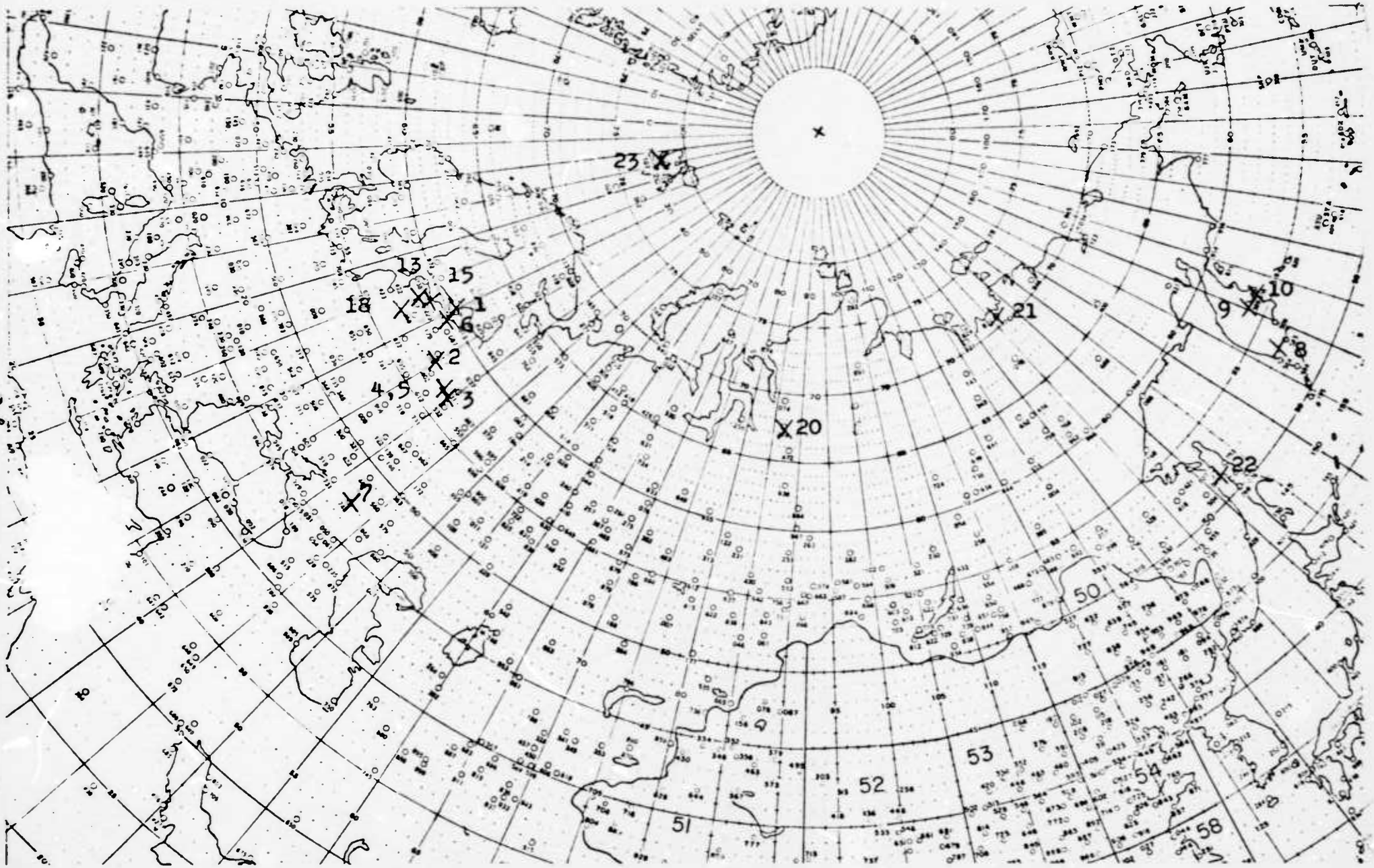


Figure 4 Location of Radiocarbon-Dated Pollen Diagrams in the U.S.S.R. (Holocene)

c) India (Bryson, Swain, Webb)

A set of calibration functions have been derived from the surface pollen data in northwestern India and time series of temperature and rainfall have been reconstructed for cores from Kuckaranzar and Didwana (see preliminary report in Bryson, 1974 (IES Report #27).

2.2 Pollen Records (the last 1000-2000 years)

Nature

The purpose of this research is to reconstruct short-term climatic changes over the past 1000-2000 years by using quantitative techniques to calibrate pollen assemblages, varve measurements, and charcoal influx in terms of climate from annually laminated (varved) sediments from lakes in northeastern North America. Because precise dating is possible from varved lakes, the climatic reconstructions from varve thicknesses and pollen counts can be used independently to verify climatic reconstructions from tree rings as well as extending the climatic record in areas where tree-ring chronologies are relatively short (less than 300 years) or are insensitive to climatic variability.

Status

Cores of varved lake sediment have now been collected from lakes in Wisconsin and during 1974, five other varved lakes were located and sampled in eastern U.S. A total of about 30 varved lakes have been found in northeastern North America (Fig. 5) of which only about 15 are adequately varved for dating purposes. This network provides a basis from which synoptic patterns of short-term changes of climate can be viewed.

Pollen and charcoal counts from a series of samples of 10 years each over a period of 1000 years have been completed from three lakes with varved sediments - 70 samples from Lake of the

Clouds (northeastern Minnesota, Swain, 1973), 40 and 30 samples from Hell's Kitchen and Dudley Lake respectively (both in north-central Wisconsin). The pollen and charcoal record at Hell's Kitchen Lake is currently being extended to cover the period from 1000 to 2000 years ago to tie in with Denton's studies (1973) on the activity of mountain glaciers over the past 2000 years.

A climatic interpretation based on the results of pollen and charcoal analysis from these three lakes suggests a "Little Ice Age" event with an increase in precipiation or a decrease in temperature or both for the period 1450 to 1850 A.D. The pollen diagrams (Figs. 6,7,8) show a decrease in the percentages of the pioneer species of jack/red pine (Pinus banksiana and P. resinosa) and birch (Betula paprifera) which requires periodic fires for adequate reproduction and an increase in the longer lived species such as hemlock (Tsuga canadensis) and spruce (Picea, sp.) which can reproduce in the absence of fire. A relative increase in moisture would result in a decreased frequency of fire and thus favor spruce at Lake of the Clouds and hemlock at Hell's Kitchen Lake and Dudley Lake. Temporary increases of white pine (P. strobus) are shown at Hell's Kitchen but are later replaced by hemlock during the 1450-1850 A.D. interval. White pine also requires fire for good reproduction but not at a frequency as short as that for jack pine or birch. Decreased values of charcoal influx and of charcoal/pollen ratios during the 1450 to 1850 interval confirm the above interpretation of a relative increase in moisture.

The beginning of agriculture in the region is marked by the increased values of ragweed (Ambrosia), grass (Gramineae), and chenopods (Chenopodium Type) during the past 70 years at the three sites. The low values of white pine and hemlock for about the last 60 years at Hell's Kitchen are probably due to logging adjacent to the lake.

Because the independent results from these three lakes agree, this strongly indicates that pollen and charcoal analysis from

varved lake-sediment provides a sufficiently sensitive proxy record of short-term climatic changes.

The calibration of the pollen records in terms of climate from these varved lakes is currently in progress (work by John Pollack) and should be complete within six months. However, the current results are still too tentative for discussion. A set of about 150 sites with modern pollen and climatic data within 600 km of Hell's Kitchen Lake provides the basis for calculating a calibration function. This function is also being used to calibrate the pollen record from Lake of the Clouds and Dudley Lake. The density of surface samples around these lakes appears adequate but further work with calibration functions may prove that more may be needed. In future calibration functions a quantitative value of soil properties at each site (provided by Dr. F. Hole, Univ. of Wisconsin, Soils Dept.) will be included with pollen and climate. At the space scale of a radius of 600 km the pollen/climate relationships may be obscured by soil properties because the soils are an important factor in determining the composition of the vegetation in many areas within the radius.

Pollen counts from Maria Boyko (1973) and Dr. J.H. McAndrews are available for two varved lakes - one 20 mi. west of Toronto, Ontario and one in Algonquin Provincial Park north of Toronto. The calibration of the pollen records from these varved lakes will be delayed until satisfactory calibration functions are developed from the three lakes described above.

Figure 5. Locations of lakes with varved sediments. Circled points indicate lakes with varves that are adequate for dating purposes.

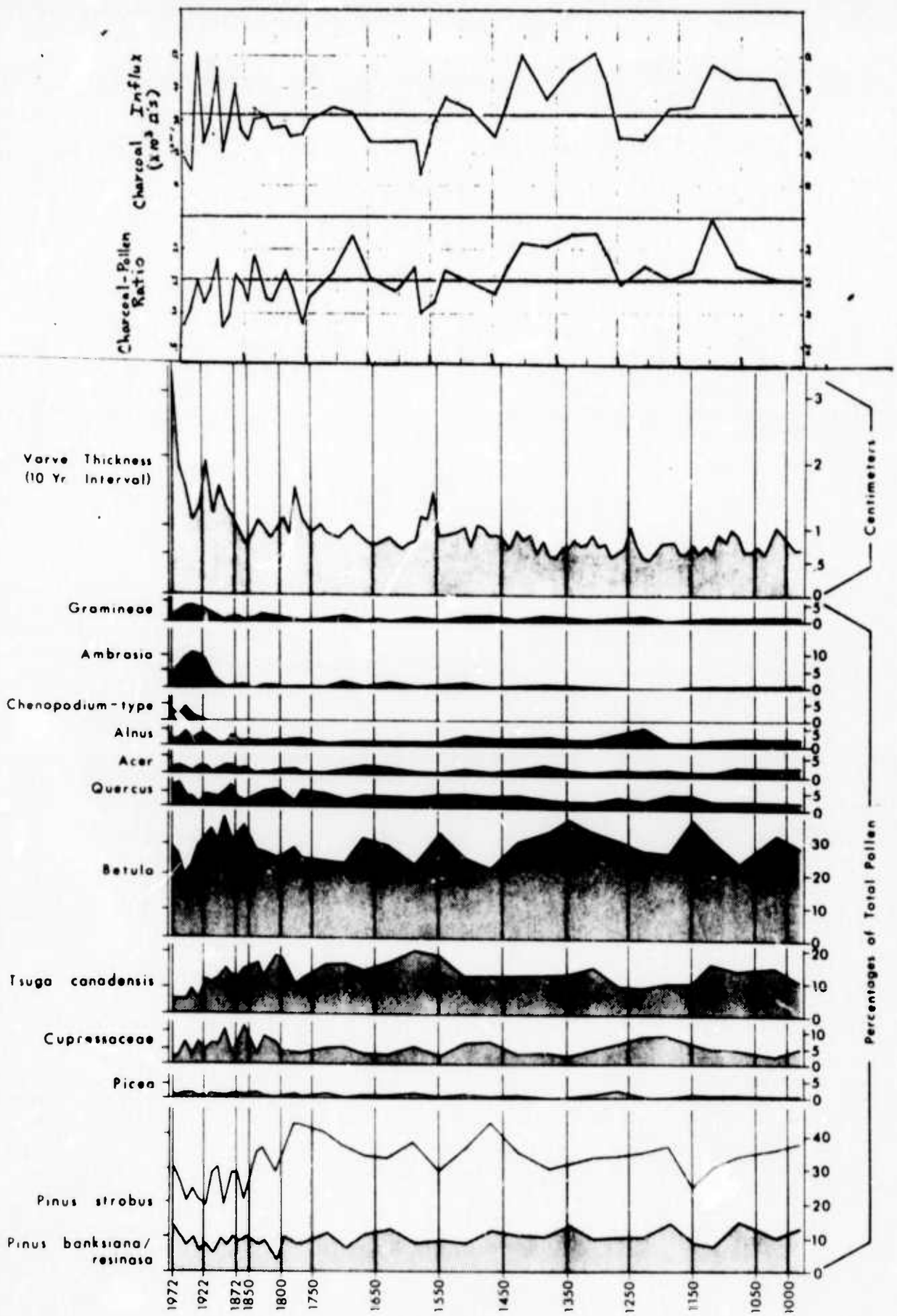


Figure 6. A 1000-year pollen and charcoal diagram from Hell's Kitchen Lake. The data points for each curve are based on 10-year averages. Note that the time scale for the charcoal curves is not identical to that for the pollen curves.

HELL'S KITCHEN LAKE
VILAS COUNTY, WISCONSIN

6.B

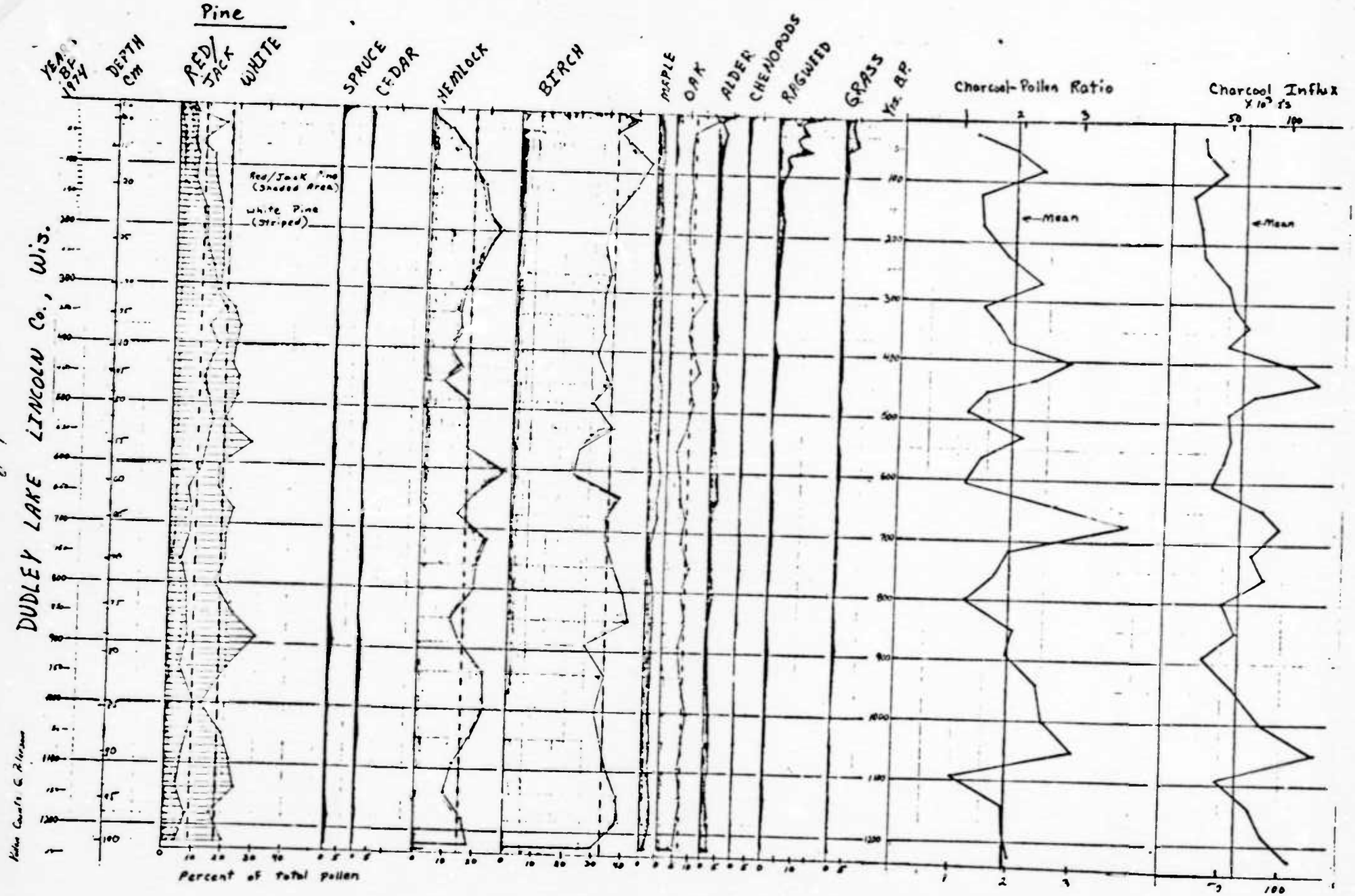


Figure 7. A preliminary draft of a 1200-year pollen and charcoal diagram from Dudley Lake. The dashed lines through several of the pollen curves represent the means for those pollen types.

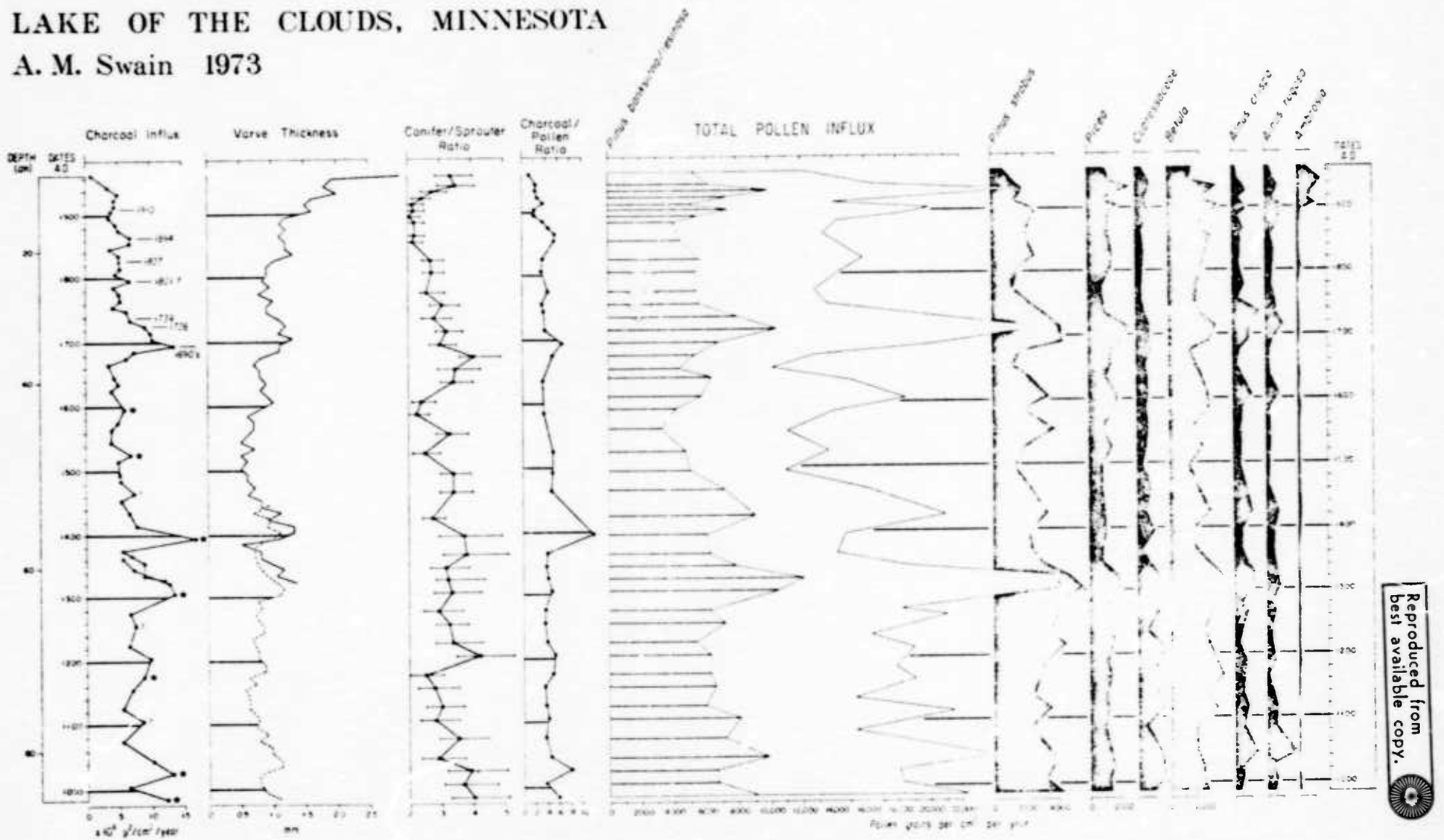


Figure 8. Charcoal and pollen influx diagram for the last 1000 years at Lake of the Clouds. The data points for each curve are based on 10-year averages.

2.3 TREE CORE RECORDS

Collection and Processing

Over 200 tree cores have been collected from seven sites in Wisconsin. The sites are located along the northern and eastern boundaries of the state. The oldest stand (red pine) is from Menominee County and extends back to about AD 1690. Two of the sites, i.e., Hell's Kitchen and Dudley Lakes (see Figure 9) are located only several miles from lakes from which varve cores have been obtained. Therefore, we have two independent records of the past from these sites. Tree-ring chronologies are typically 250 years in length.

Additionally, cores were obtained from Algonquin Provincial Park, Ontario, and from four sites from Pennsylvania to Maine during the summer of 1974. These cores were obtained from sites near varved lakes which were sampled at the same time.

Prof. P. Munson of the University of Indiana is cooperating with us to establish a long chronology of tree cores from the upper Midwest. The composite chronology will include living tree cores, plus cross-dated floating chronologies obtained from archaeological sites and buried logs recently exposed by erosion. We anticipate the development of a dendrochronological record extending several centuries into the past. The cross-dated master chronology will be used to construct climatic series contemporaneous with the trees.

All Wisconsin cores have been processed and cross-dated. Master chronologies have been prepared for the sites. This was accomplished by adopting two FORTRAN programs written by personnel at the Laboratory of Tree-Ring Research at Tucson. Several months were required to change the programs from a CDC format to our Univac system. The relationship of the master chronologies to climate will be investigated over the coming months. This will involve simple correlations and the development of calibration

functions between recent tree-growth and climate so that the relatively longer tree chronologies can be used to reconstruct climate from times prior to actual observation.

A computer program to identify missing or false rings in tree cores was developed and will be submitted for publication.

Collection of Climatic Records

An adequate sample of continuous climatic data have been assembled and punched on cards for the Wisconsin tree core sites. These include essentially century-long temperature and precipitation anomalies from the 1931-60 mean. Three to six near-by station records were used to formulate the areal mean. These will be used to identify those climatic data which correlate best with the indices of tree growth.

Calibration Functions

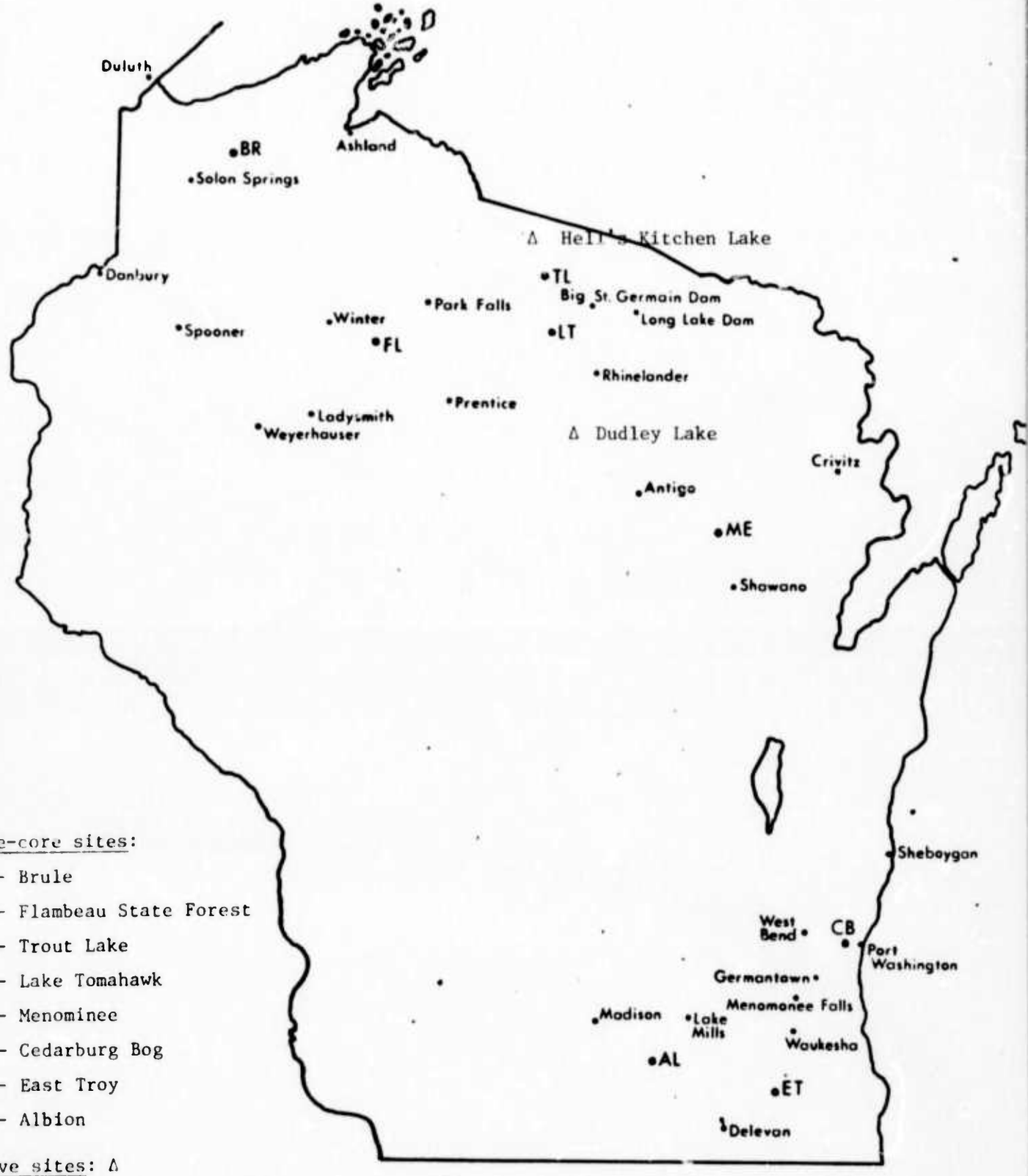
The calibration of tree indices in terms of climate is in progress. The programs and calibration functions will be developed within the next year.

2.4 COLLECTION OF HISTORICAL CLIMATIC RECORDS

A data bank of references of early accounts of weather and climate was begun under this grant. Assemblages of this sort are useful and necessary for verification of climatic reconstructions based on proxy records. The data bank includes over 670 entries. These are now punched on cards and can be sorted by time or area.

A summary of the climatic data from Hudson Bay Company's York Factory from the late 1600s to the early twentieth century will be completed within the next year. A paper is also in preparation analyzing climatic changes as noted in climatic journals from Russian Alaska (early 1800s) compared to the present. This paper will also be completed within the next year.

Figure 9. Tree-core and Varve Sites in Wisconsin.



Tree-core sites:

BR - Brule

FL - Flambeau State Forest

TL - Trout Lake

LT - Lake Tomahawk

ME - Menominee

CB - Cedarburg Bog

ET - East Troy

AL - Albion

Varve sites: Δ

Climatic Stations:

Place names given.

References

Section 2.1 (a) Pollen records - Eastern North America (Webb)

Davis, R.B. and T. Webb III (subm. for publ.), The contemporary distribution of pollen in eastern North America: a comparison with the vegetation.

Birks, H.J.B., T. Webb III, and A.A. Berti (subm. for publ.), Numerical analysis of surface pollen samples from central Canada: a comparison of methods.

Webb, T. III, and J.H. McAndrews (subm. for publ.), Corresponding patterns of contemporary pollen and vegetation in central North America.

Section 2.1 (b) Pollen records - Soviet Union (Peterson)

Grichuk, V.P. (1969), Opyt rekonstrucktsii nekotorykh elementov klimata severnogo polushariia v Atlanticheskii period golotsena. In M.I. Neishtadt, Ed. Golotsen. K VIII kongressu INQUA, Paris, 1969. Moscow, Izd-vo Nauka, pp. 41-57.

Grichuk, V.P. (1973) Paleoekologicheskie rekonstruktsii po palinologicheskimm dannym. In Akademiia nauk SSSR. Institut geografii. Paleogeografiia Evropy v pozdenm Pleistotsene. K IX Kongressu Mezhdunarodnoi Assotsiatsii po izucheniiu chetveetichnogo perioda, New Zealand, 1973. Moscow, 1973. pp. 230-232.

Neishtadt, M.I. (1957) Istoriia lesov i paleogeografiia SSSR v golotsene. Moscow, Izd-vo akademii nauk SSSR. Institut geografii.

Webb, T. III and J.H. McAndrews (subm. for publ.), Corresponding patterns of contemporary pollen and vegetation in central North America.

Section 2.2 Pollen records (last 1000-2000 years), (Swain)

Boyko,Maria (1973). European impact on the vegetation around Crawford Lake in southern Ontario. M.S. Thesis. Dept. of Botany, University of Toronto, Toronto.

Denton, G. and Karlén (1973). Holocene climatic variations - their pattern and possible cause. Quaternary Research, 3 (2): 155-205.

Swain, Albert M. (1973). A history of fire and vegetation in northeastern Minnesota as recorded in lake sediments. Quaternary Research 3 (3): 383-396.

Manuscripts or recent publications supported, partially supported or otherwise related to this grant.

Bender, Margaret M., Reid A. Bryson, and David A. Baerreis (1975) University of Wisconisn Radiocarbon Dates XII, Radiocarbon, 17 (1): 121-134.

Bernabo, J. Christopher and T. Webb III (1974) Cartographic Analysis of the Changing Time-Space Patterns in the Holocene Pollen Record of Northeastern North America. Abstracts, AMQUA 3rd Biennial Meeting, Univ. of Wisconsin-Madison, 30 July - 1 Aug. 1974, pp. 103-104.

Blasing, T.J. (Ph.D. Dissertation) Historical Climatology of Western North America and the eastern North Pacific Region.

Bryson, R.A. (1974) World Climate and World Food Systems III: The Lessons of Climatic History. IES Report No. 27, 17 pp.

Bryson, R.A. (1974) On the Analysis of Pollen-Climate Canonical Transfer Functions, Quaternary Research 4, 162-174.

Chu, Pao S. (1974) Reconstruction of the Climatic Fluctuations Over the Ohio Area, Masters Thesis, Univ. of Wisconsin-Madison. Dept. of Meteorology.

Davis, R.B. and T. Webb III (1973) Corresponding patterns of Pollen and Vegetation in Eastern North America (Abstract), INQUA Conference, Christchurch, New Zealand.

Davis, R.B. and T. Webb III (subm. for publ.) The Contemporary Distribution of pollen in Eastern North America: a Comparison with the Vegetation.

Kutzbach, J.E. and R.A. Bryson (1974) Variance Spectrum of Holocene Climatic Fluctuations in the North Atlantic Sector, Journal of Atmospheric Sciences, 31 (8): 1958-1963.

Nolte, F. Climatic History of York Factory, Canada, during the last two and one-half centuries (manuscript in preparation).

Peterson, G.M. (1974) Translation of "An attempt to Reconstruct Certain Elements of the Climate of the Northern Hemisphere in the Atlantic Period of the Holocene," by V.P. Grichuk.

Pollack, John A. (in preparation) A 1000 year Climatic Reconstruction for Northern Wisconsin Using Canonical Correlation Analysis.

Swain, A.M. (1972) A Fire History of the Boundary Waters Canoe Areas as Recorded in Lake Sediment. Naturalist 23(3) and and (4): 24-31, Autumn and Winter.

_____ (1973) A History of Fire and Vegetation in Northeastern Minnesota as Recorded in Lake Sediments, Quaternary Research 3 (3): 383-396.

_____ (in preparation) Thousand Year pollen Record of Hell's Kitchen Lake - an annually laminated lake in north-central Wisconsin.

_____ (1974) The Potential for Detailed Climatic Reconstructions in Northeastern North America from Varve Thicknesses and from Varve-dated Pollen Diagrams, Abstracts, AMQUA 3rd Biennial Meeting, Univ. of Wisconsin, Madison, 30 July - 1 Aug. 1974, p. 8.

Swain, A.M. and R.A. Bryson (in preparation) Paleoclimatic Reconstructions from Northwestern India.

Veneman, Peter L.M. Jr. Soils of Emrick Lake Drainage Basin, Marquette Co., Wis. Masters Thesis, Univ. of Wisconsin, Soils Dept.

Veneman, P.L.M. Jr., A.M. Swain and F.C. Hole (1974) Soils and Varved Sediments of the Lake Emrick Drainage Basin in Marquette County, Central Wisconsin. In Late Quaternary Environments of Wisconsin, (J.C. Knox and D.M. Mickelson, eds) A Field Guide prepared for AMQUA, 3rd Biennial Meeting, Madison Wisconsin, pp. 233-243.

Webb, T. III and J.H. McAndrews (1973) Maps of the Modern Pollen from Central North America (abstract), INQUA Conference, Christchurch, New Zealand.

Webb, T. III and J. C. Bernabo (1974) Palynological Evidence of Ecotonal Migrations in Eastern North America, Abstracts, AMQUA, 3rd Biennial Meeting, Univ. of Wisconsin-Madison, p. 26.

Webb, T. III and Douglas R. Clark (1974) On the use of Tree Rings, Pollen and Marine Plankton in Reconstructing Past Climates, Abstracts, AMQUA 3rd Biennial Meeting, Univ. of Wisconsin-Madison, 30 July - 1 August, 1974, p. 126.

Webb, T. III and McAndrews, J.H. (subm. for publ.) Corresponding patterns of contemporary pollen and vegetation in Central North America.

Webb, T. III, H.J.B. Birks, and A.A. Berti (subm. for publ.) Numerical analysis of surface pollen samples from Central Canada: a compa.ison of methods.

Wendland, Wayne M. (subm. for publ.) An Objective Method to Identify Missing or False Rings.

_____ (subm. for publ.) Wisconsin Tree Growth from AD 1700 and Tree Response to Climate.

_____ (in preparation) Climatic History of Russian America (Alaska) from the early Nineteenth Century.

Wendland, W.M. and M. Woodworth (in preparation) Bibliography of Early Climatological Sources Now Available.